§ 9. Temperature Dependence of Hydrogen Absorption Rate in Niobium Pumping Panel

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A Niobium panel is one of attractive pumping system in divertor region if neutral particle flux (atom flux) is expected to be much larger than 10^{16} /m^{2}s. Hydrogen absorption performance of the panel has been tested up to now. Recently, we found that the hydrogen absorption rate was dependent upon the temperature of Nb panel. This result is of great importance in using the panel in the low temperature range.

Figure 1 shows a schematic view of experimental device. The Nb panel is 1mm thick and 414 mm x 444 mm in size and set in a UHV chamber (~ 10^{-7} Pa). In order to heat the panel uniformly, it is a strip-type structure, which has a cut (2 mm) made alternately from both sides at intervals of 13 mm. The panel is heated up to about 700 °C by passing electric current (100 A) through the strip. The panel temperature is measured by using a thermocouple and an IR thermometer. The amount of hydrogen gas admitting into the main chamber is managed by a mass flow controller (MFC). The gas flow is also confirmed by checking the flow rate through an orifice set in the exhaust pipe. Hydrogen atom flux to the panel is produced by an atomizer, in which a Ta wire is heated up to about 1800 °C.

Hydrogen absorption by the Nb panel causes the drop of chamber pressure (upstream pressure) as shown in Fig. 2. In this case, hydrogen gas is admitted so as to keep the pressure 1 Pa H_2 (constant gas flow rate). When the atomizer turns on, the temperature of the atomizer reaches the maximum after 23 s and the atom flux becomes constant. Here, we can see a big difference in the time variation of the upstream pressure (hydrogen absorption rate) for experiments with different initial panel temperatures. This suggests that the hydrogen absorption rate depends on the temperature of Nb panel. Since the panel is heated by the radiation from the atomizer, the absorption rate increases with time for the low temperature case. Figure 3 shows the pumping rate of the panel as a function of the panel temperature. These data points indicate the pumping rate and the panel temperature at 23 s after the atomizer switched on. The pumping rate remarkably decreases in the low temperature range (< 200 °C). In our device, it is very difficult to carry out the experiment keeping the panel at room temperature because of panel heating due to radiation from the atomizer. However, if we extrapolate the pumping rate at room temperature, it seems to be extremely low. This may be caused by the formation of a multilayer impurity coverage, which is not "transparent" for thermal H atoms. At low temperature, the diffusion of impurities in the metal bulk is frozen and all impurity atoms being deposited on the surface remain in the surface/subsurface zone. The impurity must be O or CO, but it is not specified yet.

In conclusion, the Nb panel for hydrogen pumping should be operated at the temperature more than 200 °C to keep an effective H absorption rate.

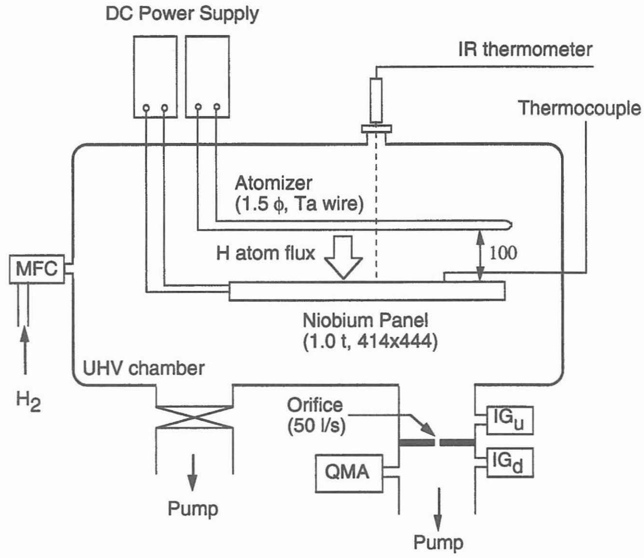

Fig. 1. A schematic view of experimental setup for testing a Nb pumping panel.

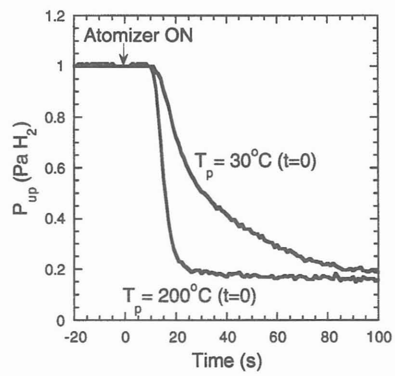

Fig. 2. Time history of upstream pressure in producing hydrogen atoms by an atomizer for the panel with different temperatures.

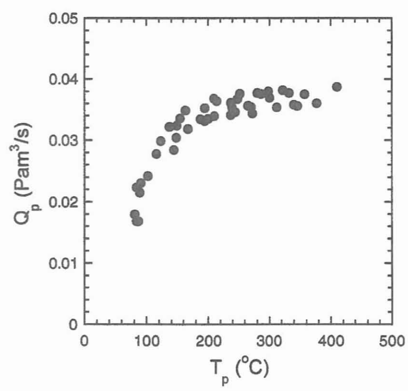

Fig. 3. Dependence of pumping rate on panel temperature.